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TECHNICAL MEMORANDUM

TO: Mark Edens, Washington State Department of Ecology

FROM: Will Hafner (Newfields) and Iris Winstanley (SAIC)

DATE: January 28, 2011

SUBJECT: Stormwater Contaminant Loading to Slip 4 from KCIA SD#3/PS44 EOF

Introduction

Science Applications International Corporation (SAIC) was tasked by the Washington State Department of Ecology (Ecology) with the collection of stormwater and continuous flow measurements from the storm drain (SD) lines upstream of the King County International Airport (KCIA) SD#3/PS44 emergency overflow (EOF) outfall to Slip 4 between September 2009 and June 2010.

Preliminary stormwater sampling began at two locations in September 2009. Stormwater sampling was expanded to additional events and locations in February 2010. The sampling results are reported in the Preliminary Stormwater Sampling Interim Data Report (SAIC 2010) and the Expanded Stormwater Sampling Interim Data Report (SAIC 2011). These data reports summarize the measured concentrations of chemicals of potential concern (COPCs) in whole water and filtered solids samples, and compare these concentrations to relevant regulatory criteria. Issues related to the collection of continuous flow measurements are also discussed in these reports.

A list of sampling locations and sample types collected is presented below. This information is presented in more detail in the Interim Data Reports. All sampling locations are shown in Figure 1.

SAIC collected continuous flow measurements and whole water and filtered solids samples from 10 storm events and two base flow sampling events between September 2009 and June 2010 at the following locations:

- LS431, located on the discharge (southwest) side of the KC lift station. All four lateral SD lines plus the Building 3-380 line drain to the lift station prior to entering Slip 4.
- MH108, located along the north lateral SD line, north of Building 3-380 and near the corner of Building 3-350. MH108 was selected to represent stormwater drainage from the north lateral SD line. MH108 is 275 feet upstream of the connection between the north and north-central SD lines.

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SAIC collected continuous flow measurements and filtered solids from three storm events between April 2010 and June 2010 at the following locations:

- MH356, located on the southwestern corner of Building 3-369, approximately 150 feet upgradient of the lift station. This location is near the downstream end of the south lateral SD line.
- MH369, located at the north end of the small parking lot on the northwest side of Building
3-390. This location is 700 feet upgradient of the lift station on the south central lateral SD line.
- MH226, located in a flight apron 190 feet north of MH369. MH226 is on the north central lateral SD line, 350 feet upgradient of the junction with the north lateral SD line.
- CB423, located between Building 3-380 and the lift station. Flow through CB423 is representative of the Building 3-380 drainage.
- MH434, located 75 feet downstream of the lift station. MH434 is representative of flow from a section of parking lot bordering East Marginal Way S and additional parking spaces within NBF. MH434 was the only drainage area sampled that does not drain to the lift station.

This technical memorandum describes the combination of stormwater concentration and flow data into estimates of contaminant mass loading. All loadings are calculated using Ecology's *Standard Operating Procedure for Calculating Pollutant Loads for Stormwater Discharges* as a guide (Ecology 2009a). This memorandum is intended to quantify total contaminant loadings from the North Boeing Field, Georgetown Steam Plant, and King County International Airport properties, and the relative mass of contaminants from each of the lateral lines, to Slip 4 via the KCIA SD#3/PS44 EOF outfall. It does not evaluate loadings to Slip 4 from other sources, nor does it compare loadings to current contaminant concentrations in Slip 4 sediments.

Stormwater Runoff Volumes

Although continuous flow measurements were collected at each of the locations described above, the measured flows at several of these locations are not believed to be representative of actual conditions (SAIC 2011), as discussed in the *Expanded Stormwater Sampling Interim Data Report* (SAIC 2011) . Therefore, contaminant mass loading calculations presented in this memorandum use predicted stormwater flows, derived from the size of the drainage area for each lateral SD line as described below, rather than measured flow values.

Table 1 lists the surface area of each lateral SD line drainage area within the NBF-GTSP boundary (onsite), and the approximate surface area of each drainage area extending into KCIA (offsite). Onsite and offsite areas for the individual lateral lines were calculated using maps of the SD structures and a Thiessen polygon analysis (Figure 2). Additional estimates of offsite surface areas were calculated by Boeing for the *North Boeing Field Stormwater Pollution Prevention Plan* (SWPPP; Boeing 2010).

SAIC's surface area estimates are used to predict flows for each lateral SD line. The SAIC estimates were calculated using the same method for onsite and offsite drainages and they take into account the large amounts of impervious surface found in the north SD line and in offsite properties.

Predicted flow was determined using a runoff volume equation presented in *Standard Operating Procedure for Automatic Sampling for Stormwater Monitoring* (Ecology 2009b).

Equation 1. Predicted runoff volume

$$V_R = \frac{PF}{12} * Area * RC$$

Where:

- V_R is runoff volume (ft^3)
- PF is the precipitation total (inches)
- Area is the drainage area (ft^2)
- RC is a runoff coefficient equal to 0.009 * (% Impervious Surface) + 0.05

Table 2 shows the total volume (in gallons) of predicted runoff volume from the NBF-GTSP and KCIA lateral line drainages for the sampling year that began in September 2009 and ended August 2010. A total of 43.1 inches of precipitation fell during this period.

Several sources of error exist within the predicted volume calculation. The easiest to quantify is the error due to incorrectly estimating the surface area of each lateral line drainage sub-basin. From Table 1, the percent difference between the total area of each lateral line using SAIC estimates and Boeing SWPPP estimates averages about 25 percent. This number is assumed to be the error present in all predicted runoff volumes in Table 2, including LS431.

Base flow is also included in Table 2 for the wet (October 1 through May 30) and dry (May 1 through September 30) seasons. The only available estimate of base flow comes from the measured flows at MH108 and LS431. Precipitation-free periods of three or more days were used to extrapolate base flow over the wet and dry seasons. Equipment at both sites was removed in early July 2010. Dry season flow estimates are biased high due to lack of July and August base flow data.

Base flow was not observed at CB423, MH434, or MH226. The presence of base flow in the south and south central lateral lines could not be determined due to the presence of standing water. For this memorandum, base flow at each of these two locations is assumed to be one-half the difference between base flow at LS431 and MH108 (Table 2).

Potential errors in the base flow volumes are much greater. The level and velocity measured by the flow sensor at MH108 during base flow conditions were reasonable based on observations from the surface. A low error of plus or minus 5 percent has been applied to the north lateral storm drain line. Measurements at LS431 were more variable. Problems with the level readings at LS431 are reported in *Expanded Stormwater Sampling Interim Data Report* (SAIC 2011). Modified level readings were used to report base flow at LS431, however estimated base flows would be more than three times lower if this adjustment were not used. The error estimated for base flow measurements at LS431 ranges from +5 percent to -70 percent. Base flow in the south and south central SD lines could be as low as zero, or as high as twice the values reported in Table 2. Errors of plus or minus 100 percent have been assigned to these locations.

Loading Calculation Method

The total annual mass load has been calculated using the methods presented in Ecology's *Standard Operating Procedure for Calculating Pollutant Loads for Stormwater Discharges* (Ecology 2009a). Loadings are calculated and reported separately for whole water and filtered solids samples. Whole water loadings are the product of annual mean concentration and annual flow volume (Equation 2). Filtered solids loadings are the product of annual mean concentration, annual mean total suspended solids (TSS), and annual flow volume (Equation 3).

Equation 2. Total annual mass load for whole water

$$ML = (V_{bd} * C_b) + (V_{bw} * C_b) + (V_s * C_s) * CF$$

Equation 3. Total annual mass load for filtered solids

$$ML = (V_{bd} * TSS_b * C_b) + (V_{bw} * TSS_b * C_b) + (V_s * TSS_s * C_s) * CF$$

Where:

- ML is the total annual mass load (g or kg/yr).
- V_{bd} is the base flow volume in the dry season (gal).
- V_{bw} is the base flow volume in the wet season (gal).
- V_s is the total annual storm flow volume (gal).
- C_b is the average annual flow-weighted base flow concentration (ug/L, mg/kg).
- C_s is the average annual flow-weighted stormwater concentration (ug/L, mg/kg).
- TSS_b is the average annual flow-weighted base flow TSS concentration (mg/L).
- TSS_s is the average annual flow-weighted stormwater TSS concentration (mg/L).
- CF is a conversion factor to convert gallons to liters and mg or ug to kg.

V_{bd}, V_{bw}, and V_s are presented in Table 2. The annual average flow-weighted base flow concentrations (C_b) and annual average flow-weighted stormwater concentrations (C_s) for whole water and filtered solids are calculated below.

Flow-Weighted Base Flow Concentrations

Annual mean base flow concentrations were calculated using a flow-weighted mean approach.

Equation 4. Base flow annual flow-weighted mean concentration

$$C_b = \frac{\sum C_{bi} * BF_i}{\sum BF_i}$$

Where:

- C_{bi} is the base flow concentration for event i, where i = 2 events (ug/L or mg/kg). Equation 4 was not needed if concentrations were measured for only one base flow event.
- BF_i is the volume of base flow for event i divided by the event sampling duration (gal).

Flow-weighted mean concentrations for base flow are presented in Tables 3 and 4 for filtered solids and whole water, respectively. Only two base flow samples were collected at MH108 and LS431. The relative standard deviations (standard deviation divided by average of samples) are presented as estimates of error for the flow-weighted means for MH108 and LS431. Base flow concentrations at MH369 and MH356, on the south central and south lateral SD lines, are estimates. These numbers represent the concentrations necessary to dilute base flow from MH108 to the levels observed at the lift station. Errors on these estimated concentrations are assumed to be 100 percent. Base flow concentrations for total PCBs and mercury could not be calculated at MH369 and MH356 using this method.

Flow-Weighted Stormwater Concentrations

Whole water or filtered solids concentrations collected from individual storm events consist partially of base flow and are influenced by base flow concentrations. Removing base flow concentrations from storm flow assumes that base flow infiltration rates observed during dry periods continue during periods of precipitation. Equation 5 is used to remove the influence of base flow.

Equation 5. Corrected storm flow concentrations for each event

$$EMC_S = \frac{EMC_{tot} - C_b * f_b}{f_s}$$

Where:

- EMC_S is the event mean concentration corrected to storm flow (base flow concentrations removed)(ug/L or mg/kg).
- EMC_{tot} is the event mean concentration including storm flow and base flow concentrations (ug/L or mg/kg).
- f_b is the fraction of event flow attributed to base flow.
- C_b is the base flow concentration calculated from Equation 4 (ug/L or mg/kg).
- f_s is the fraction of event flow attributed to storm flow.

When base flow concentrations are much higher than those observed during storm events, Equation 5 has the effect of reducing measured storm flow concentrations. This situation is true for total PCBs in whole water and filtered solids at MH108.

Not all storm flow concentrations were corrected for base flow. For example, high molecular weight polyclic aromatic hydrocarbon (HPAH) concentrations were not measured in either of the base flow filtered solids samples. Highlighted analytes in Tables 3 and 4 were corrected to remove base flow concentrations.

Annual mean storm flow concentrations were calculated using a flow-weighted mean approach similar to that shown in Equation 4.

Equation 6. Storm flow annual flow weighted mean concentration

$$C_s = \frac{\sum EMC_{si} * SF_i}{\sum SF_i}$$

Where:

- EMC_{si} is the storm flow concentration from Equation 5 for event i, where i = 1 to 11 events (ug/L or mg/kg).
- SF_i is the volume of storm flow for event i divided by the event sampling duration (gal).

Total Annual Mass Loadings

Total annual mass loadings for TSS, total PCBs, total HPAH, mercury, cadmium, copper, lead, and zinc have been calculated for whole water using Equation 2. Total annual mass loadings for total PCBs, total HPAH, mercury, cadmium, copper, lead, and zinc have been calculated for filtered solids using Equation 3.

TSS measurements in the whole water samples were considered more reliable than those calculated from the filtered solids samples (see recommendations in Section 5.0 in SAIC 2011). As a result, whole water TSS measurements are used in Equation 3 for calculation of filtered solids loadings. TSS for LS431 and MH108 were based on measured values. The annual mean TSS concentrations at LS431 and MH108 were 29 and 31.5 mg/L, respectively (Table 4). Using the storm flow volumes from Table 2, the remaining lateral lines would need to have average TSS concentrations of 28.3 mg/L to equal TSS loads coming from the lift station. An error of plus or minus 90 percent has been applied to this estimate. This error is close to the greater of the relative standard deviations of TSS for LS431 and MH108 (Table 4). Using the same process, the estimated TSS for MH356 and MH369 during base flow conditions is 29.3 mg/L.

Loadings for TSS and each of the chemicals of potential concern are summarized in separate below. Tables include annual loadings for both storm and base flow. Total loadings are in units of grams per year for total PCBs, HPAH, mercury and dioxins. All other loadings are in units of kilograms per year. Errors for each of the measurements reported in Tables 2 through 4 are propagated through the loading calculations. Relative error ranges are reported with each loading estimate.

The loadings contribution from each lateral SD line relative to LS431 is presented in a summary figure for each chemical. Relative loadings are calculated as the storm flow loading for each lateral line divided by the sum of storm flow and base flow loadings at LS431 and the base flow loading for each lateral line divided by the sum of storm flow and base flow loadings at LS431.

Total Suspended Solids (TSS)

The product of volume and TSS is the mass loading of solids in units of kg/yr (Table 5). Because of the similarities in TSS concentrations between lateral SD lines, TSS loadings are driven mainly by flow volume. Total mass loading of TSS through LS431 are estimated to be 28,400 kg/yr for storm flow and an additional 15,700 kg/yr for base flow. The south lateral SD line is the largest contributor of TSS, with 11,500 kg/yr. The Building 3-380 drainage and the parking lot are minor contributors, with a combined total of about 1,300 kg/yr.

Total PCBs

Total filtered solids PCB loadings to Slip 4 were 0.036 kg/yr for storm flow and 0.017 kg/yr for base flow (Table 5). Whole water loadings had similar values with 0.033 kg/yr for storm flow and 0.0082 kg/yr for base flow (Table 6). The north lateral SD line was the primary source of PCB loadings.

Storm flow loadings from filtered solids in the north lateral SD line were about half of the total loadings at LS431 (0.018 kg/yr for filtered solids). As calculated, the base flow loadings for the north line were over three times higher than base flow loadings at LS431 (Table 5). This large discrepancy is likely due to a poor estimation of base flow volume at both locations, rather than concentration differences.

The average concentrations of total PCBs measured in base flow samples at MH108 were 15 to 20 times higher than at LS431 for both filtered solids and whole water (Tables 3 and 4). With such large concentration differences, small errors in estimating base flow volumes have large implications for the accuracy of loading calculations.

Even if the magnitude of the base flow loadings is not correct, base flow from the north lateral SD line remains the largest source of PCB loadings to Slip 4 (Figure 3). Relative storm flow loadings in the north lateral SD line were higher than those from the other lateral lines. However, storm flow loadings in the north lateral SD line were about one-third of base flow loadings.

Given the high concentrations of PCBs in base flow at MH108 compared to LS431, any PCB concentrations present in base flow from the south and south central lateral SD lines would have to be much lower than concentrations measured at LS431. No estimate of base flow loadings from the south and south central lines could be calculated.

The parking lot is the only sampled area that does not drain through the lift station. PCB loadings from the parking lot were 0.00057 kg/yr. Because this location was influenced by tides and water discharged from LS431, the concentrations used in the loadings calculations may have been biased. Sweep samples from the parking lot were collected and analyzed as a confirmation for the storm flow samples collected from MH434 (SAIC 2011). PCB concentrations in the sweep samples were lower than those from MH434, suggesting that loadings from the parking lot may be lower than reported.

Total HPAH

Total loadings of HPAH from LS431 in storm flows were estimated at 0.64 kg/yr using filtered solids concentrations (Table 5) and 2.7 kg/yr using whole water concentrations (Table 6). The reason for this difference is not clear.

For filtered solids, the sum of HPAH loadings from the four lateral lines was higher than the loadings calculated for the lift station. The north lateral SD line contributed 20 to 25 percent of HPAH loadings. The south lateral SD line was the largest contributor, with nearly 90 percent of total loadings (Figure 4).

Base flow loadings of HPAH in whole water were less than one percent of storm flow loadings at MH108, and 3.5 percent of storm flow loadings at LS431. No base flow filtered solids samples were analyzed for HPAH. Given the results of the whole water base flow samples, it is unlikely there is a significant contribution to base flow loadings in filtered solids.

Mercury

Mercury was not detected in any whole water samples. Filtered solids loadings at LS431 were 0.011 kg/yr (Table 5). The north lateral SD line is the largest contributor of mercury, with nearly 60 percent of the total mass loading (Figure 5). Twenty five percent of mercury loadings came from the south lateral SD line.

Storm flow loadings from the north lateral SD line were 0.0045 kg/yr, while base flow loadings were 0.0029 kg/yr (Table 5). Like PCBs, base flow loadings were higher at MH108 than at LS431.

Cadmium

Total cadmium loadings from LS431 were 0.21 kg/yr and 0.58 kg/yr for filtered solids (Table 5) and whole water (Table 6), respectively. Whole water loadings represent total cadmium. Dissolved cadmium was only detected in three samples.

Cadmium loadings from the north, north central, and south central lateral SD lines ranged between 15 and 30 percent of total loadings. The south lateral line represented nearly 75 percent of total loadings (Figure 6). The sum of loadings from the individual lateral lines exceeds the total loadings from LS431.

Whole water base flow loadings at LS431 were 6.3 kg/yr, compared to 0.064 kg/yr for filtered solids. The cadmium concentrations from the first base flow sample were about 15 ug/L at both LS431 and MH108. Concentrations from the second base flow sample at both locations were undetected (0.1 ug/L). More whole water base flow samples are needed to develop a better estimate of base flow loadings for cadmium.

Copper

Copper loadings are highest in the south lateral SD line, followed by the north and north central lines (Figure 7). Loadings calculated from whole water data are higher than those from filtered solids. Approximately one-third of total whole water loadings consist of dissolved phase copper loadings (Table 6). If dissolved phase loadings are subtracted from the total, whole water loadings are similar to those from filtered solids.

Base flow loadings for filtered solids and total whole water are 5 to 15 percent of storm flow loadings. Base flow loadings for dissolved whole water constitute a much higher percentage of total storm flow loadings (Table 6). Dissolved concentrations of copper were higher than total concentrations in the base flow samples, suggesting analytical issues may be responsible for the magnitude of dissolved phase base flow loadings.

Lead

Lead storm flow loadings were of a similar magnitude for whole water and filtered solids. Loadings from LS431 averaged about 3.2 kg/yr (Table 5), while loadings from MH108 were close to 1.8 kg/yr.

The south lateral line was the largest source, with up to 60 percent of the total lead loading. The north lateral line was the next largest source with about 30 percent of the total. Like many of the metals, lead loading at LS431 is lower than the sum of loadings from the other lateral lines (Figure 8).

Base flow loadings were 2.6 kg/yr at the lift station, compared to 0.066 kg/yr at MH108 on the north lateral line. The difference in loading between the two locations was split between the south and south central lateral lines.

Zinc

Zinc had the highest mass loadings of any COPC. Loadings from the lift station were estimated at 21.8 kg/yr for filtered solids and 68 kg/yr for whole water. Dissolved phase whole water loadings were 28.7 kg/yr at the lift station (Table 6).

The south lateral line was the largest contributor of zinc, at around 60 percent. The north, north-central, and south-central lines contributed between 25 and 30 percent of the total (Figure 9). Base flow loadings ranged from 10 to 20 percent of total storm flow zinc loadings.

Dioxin/Furan TEQ

Dioxin/furan loadings were calculated using TEQ normalized concentrations (SAIC 2011). Dioxin/furan TEQ loadings at LS431 were 1.0 E-06 kg/yr for filtered solids (Table 5). Whole water samples were not analyzed for dioxin/furan congeners.

The north lateral SD line was the largest contributor, at nearly 80 percent of the total dioxin/furan TEQ loading. The north central line was the next largest source (Figure 10). Base flow made up five percent of total dioxin TEQ loading in the north lateral line, and about three percent of the total at LS431.

There are some uncertainties in the calculations of loadings for dioxin/furan TEQs. Dioxins were only measured in three samples at MH108 and LS431, and only one sample in the other lateral SD lines. Concentrations in the first two samples at MH108 and LS431 were an order of magnitude higher than those in the third sample. Analysis of additional samples for dioxin/furan congeners is needed to obtain a more representative concentration for each location.

Summary and Recommendations

Physical and chemical loadings were calculated for each of the storm drain lines at NBF-GTSP. Loadings were calculated separately for storm and base flow conditions.

The north lateral SD line was the largest source of PCB loading to the lift station. Base flow loading was a major constituent of total PCB loading from the north lateral line. Mercury loading was also highest in the north lateral SD line. Loadings of HPAH, cadmium, copper, lead and zinc were all highest in the south lateral SD line, partly due to the large volume of flow from this line. For many of the COPCs, the sum of loadings from the individual lateral lines was greater than the total loading calculated at LS431. For all chemicals, the smaller Building 3-380 drainage and the parking lot drainage were not major contributors to total loading.

There were several issues that occurred during stormwater sampling that could have impacted the loading calculations. The issues and possible solutions are listed below:

- TSS measurements from the solids filtration system were not usable (SAIC 2011). Instead, whole water TSS values were used to calculate loading at MH108 and LS431, while estimated values were used at the other locations. Inside the filter housing, the filter bag sits in a protective basket. This basket maintains the seal between the filter bag and the filter housing. Under pressures between 15 and 20 psi, this basket can flex. Once the basket flexes, the seal is lost and water can flow through the system without passing through the filter bag. This may have happened during filtered solids sampling at NBF. A pressure relief valve would limit the water pressure that contacts the protective basket. A smaller pump may have the same effect, but would represent a major design change. Until the issue is resolved, collection of whole water grab samples is recommended at all sampling locations to make sure a valid TSS measurement is available.
- Filtered solids samples at MH369 and MH356 were collected from portions of the south central and south lateral SD lines that are continually inundated with water backed up from the lift station. SAIC reviewed the CAD files for NBF and found that at MH356, water could back up as far up the main lateral as MH281, nearly 610 feet upstream of MH356. In addition, water backs up east of MH353 in a tributary to the main lateral. It backs up beyond OWS 1-C and beyond MH401 through the SD line under Building 3-390. It may reach almost to the middle of the building for a total length of approximately 575 ft upstream of MH353. At MH369, water can back up in the main lateral almost to CB409, for a total length of approximately 930 ft upstream of MH369. Given the extent of the storage capacity for the lift station, it will be difficult to find locations in the south

central and south lateral lines that are not impacted by the lift station, yet still represent a significant portion of the drainage area.

- The accuracy of base flow measurements at MH108 and LS431 could be improved. More accurate measurement of base flow may correct the inconsistency of higher base flow loadings at MH108 than at LS431 for PCBs and mercury. Flow conditions at both locations are difficult to measure with existing Isco equipment. Base flow at MH108 consists of slow-moving, clear water. The Isco flow sensor does a poor job of measuring velocities under 1 foot/second, especially in clear water. Installing a bubbler or similar device upstream of the flow sensor at MH108 may increase the accuracy of the velocity readings and help achieve a better assessment of base flow. Issues with measuring flow have been discussed in SAIC 2011.
- There were differences between whole water and filtered solids loadings for many of the COPCs. It is not clear how and why the two sampling systems differ.
- PAHs were not measured in any of the base flow filters. Based on whole water base flow samples, PAHs do not appear to be present at high concentrations in base flow samples. If additional base flow filters samples are collected, these should be analyzed for PAHs to verify this conclusion.
- For HPAH, cadmium, copper, lead, and zinc, the sum of loadings from the individual drainages is greater than the total loading at the lift station. This should be investigated further.
- Boeing has begun treatment of stormwater and base flow for PCBs in the north lateral SD line. The north line represented the majority of total PCB loadings. Stormwater and base flow sampling should continue at MH108 and at LS431, including collection of continuous flow measurements. Continued collection of data will allow comparison of pre- and post-treatment stormwater and base flow loadings.

References

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Table 1
NBF-GTSP Stormwater Drainage Areas

	North MH108	North Central MH226	South Central MH369	South MH356	3-380 CB423	Total LS431	Parking Lot MH434
Onsite Total Area (acres)							
SAIC[1]	20.22	22.31	25.69	52.28	3.99	124.49	7.08
Boeing SWPPP[2]	--	--	--	--	--	--	--
Onsite Pervious Area (acres)							
SAIC[1]	1.99	--	--	--	--	1.99	--
Boeing SWPPP[2]	--	--	--	--	--	--	--
Offsite Total Area (acres)							
SAIC[1]	45.77	30.84	34.28	55.18	--	166.06	--
Boeing SWPPP[2]	30.60	49.70	56.30	34.40	--	171.00	--
Offsite Pervious Area (acres)							
SAIC[1]	17.34	14.76	17.22	11.61	--	60.93	--
Boeing SWPPP[2]	--	--	--	--	--	--	--

Onsite: within NBF-GTSP site boundary
Offsite: within KC property, outside of NBF-GTSP site boundary
1: SAIC estimates based on Thiessen polygon analysis of storm drain structures
2: Boeing 2010; presented for comparison

Table 2
Storm Flow and Base Flow Volumes Used in Loading Calculations

	North MH108	North Central MH226	South Central MH369	South MH356	3-380 CB423	Total LS431	Parking Lot MH434
Total Annual Storm Flow Volume from Area-Based Predictions (million gallons) - V_s							
	55.1 ±25%	43.5 ±25%	48.5 ±25%	107 ±25%	4.43 ±25%	259 ±25%	7.88 ±25%
Base Flow Annual Volume from Measured Average Flows (million gallons)							
Wet Season (V_{bw})	21.1 ±25%	-- --	40.0 ±100%	40.0 ±100%	-- --	101 +25% / -70%	-- --
Dry Season (V_{bd})	7.93 ±25%	-- --	20.1 ±100%	20.1 ±100%	-- --	48.0 +25% / -70%	-- --

Table 3
Flow-Weighted Annual Mean Concentrations of COPCs in Filtered Solids

	Total PCBs mg/kg		Total HPAH[1] mg/kg		Mercury mg/kg		Cadmium mg/kg		Copper mg/kg		Lead mg/kg		Zinc mg/kg		Dioxin TEQ ng/kg	
Storm Flow																
N-MH108	2.8	±220%	20.6	±44%	0.69	±100%	10.1	±37%	339	±14%	267	±37%	1220	±18%	121	±78%
NC-MH226	0.45	±24%	34.3	±67%	0.34	±17%	14.0	±45%	302	±44%	260	±23%	1690	±41%	44.6	±100%
SC-MH369	0.70	±60%	6.23	±10%	0.18	±33%	7.8	±34%	139	±21%	71.3	±67%	847	±16%	17.3	±100%
S-MH356	0.55	±51%	62.6	±32%	0.26	±33%	16.2	±7.9%	268	±6.5%	208	±19%	1550	±4.1%	6.6	±100%
3-380-CB423	0.85	±96%	2.76	±100%	0.19	±45%	4.9	±7.1%	183	±48%	145	±35%	1590	±16%	45.4	±100%
LS431	1.3	±84%	22.6	±46%	0.39	±170%	7.5	±26%	141	±43%	111	±70%	767	±31%	36.5	±100%
PL-MH434	0.67	±15%	16.5	±19%	0.14	±38%	3.9	±25%	129	±31%	188	±25%	1050	±23%	65.5	±100%
Base Flow																
N-MH108	23.5	±9%	--		1.2	±120%	3.3	±32%	117	±57%	27.6	±13%	315	±2.2%	17.7	±72%
NC-MH226	--		--		--		--		--		--		--		--	
SC-MH369	--		--		--		4.2	±100%	21.7	±100%	201	±100%	214	±100%	0.010	±100%
S-MH356	--		--		--		4.2	±100%	21.7	±100%	201	±100%	214	±100%	0.010	±100%
3-380-CB423	--		--		--		--		--		--		--		--	
LS431	1.1	±0.67	--		0.10	±64%	4.1	±33%	39.9	±44%	168	±120%	234	±7.6%	2.2	±100%
PL-MH434	--		--		--		--		--		--		--		--	

1: HPAH was not measured in filtered solids base flow samples
Shaded storm flow concentrations were corrected for base flow
N: North lateral storm drain line
NC: North central lateral storm drain line
SC: South central lateral storm drain line
S: South lateral storm drain line
3-380: Building 3-380 drainage area
PL: Parking lot drainage

Table 4
Flow-Weighted Annual Mean Concentrations of COPCs in Whole Water

	TSS mg/L		Total PCBs ug/L		Total HPAH ug/L		Cadmium Total ug/L		Cadmium Diss.[1] ug/L	Copper Total ug/L		Copper Diss. ug/L		Lead Total ug/L		Lead Diss.[1] ug/L	Zinc Total ug/L		Zinc Diss. ug/L	
Storm Water																				
N-MH108	31.5	±87%	0.034	±150%	3.4	±130%	0.84	±590%	--	19.7	±52%	6.6	±42%	8.0	±84%	--	100	±26%	62.4	±19%
LS431	29.0	±66%	0.033	±91%	2.8	±88%	0.59	±230%	--	10.9	±46%	2.4	±96%	6.2	±68%	--	69.4	±35%	29.3	±29%
Base Flow																				
N-MH108	21.7	±89%	0.25	±14%	0.059	±130%	7.3	±140%	--	3.3	±29%	5.0	±110%	1.4	±43%	--	14.6	±14%	10.1	±120%
LS431	27.8	±0%	0.015	±9.7%	0.18	±72%	11.2	±100%	--	1.3	±74%	8.0	±89%	2.2	±81%	--	15.4	±16%	17.2	±92%

1: Dissolved Cadmium was only detected in two samples, dissolved lead was not detected in any samples. Concentrations are not included for loadings calculations.

Shaded storm flow concentrations were corrected for base flow

N: North lateral storm drain line

Table 5
Predicted Annual Mass Loading Based on Filtered Suspended Solids Samples
September 2009 through August 2010

	North MH108	North Central MH226	South Central MH369	South MH356	3-380 CB423	Total LS431	Parking Lot MH434
Total PCBs (kg/year)							
Storm Flow	0.018	0.0021	0.0036	0.0063	0.00040	0.036	0.00057
Error (-/+)	-110% / +650%	-94% / +190%	-97% / +280%	-96% / +260%	-100% / +370%	-96% / +280%	-94% / +170%
Base Flow	0.056	--	--	--	--	0.017	--
Error (-/+)	-92% / +160%	--	--	--	--	-90% / +110%	--
Total HPAH (kg/year)							
Storm Flow	0.14	0.16	0.032	0.72	0.0013	0.64	0.014
Error (-/+)	-95% / +240%	-98% / +300%	-93% / +160%	-95% / +210%	-100% / +380%	-86% / +200%	-94% / +180%
Base Flow	NA	NA	NA	NA	NA	NA	NA
Error (-/+)	NA	NA	NA	NA	NA	NA	NA
Mercury (kg/year)							
Storm Flow	0.0045	0.0016	0.00091	0.0030	0.000091	0.011	0.00012
Error (-/+)	-100% / +370%	-94% / +180%	-95% / +220%	-95% / +220%	-96% / +240%	-120% / +460%	-95% / +230%
Base Flow	0.0029	--	--	--	--	0.0016	--
Error (-/+)	-100% / +420%	--	--	--	--	-89% / +110%	--
Cadmium (kg/year)							
Storm Flow	0.066	0.065	0.040	0.19	0.0023	0.21	0.0033
Error (-/+)	-94% / +220%	-96% / +240%	-95% / +220%	-93% / +160%	-93% / +150%	-81% / +160%	-94% / +200%
Base Flow	0.0078	--	0.028	0.028	--	0.064	--
Error (-/+)	-94% / +210%	--	-100% / +660%	-100% / +660%	--	-80% / +66%	--
Copper (kg/year)							
Storm Flow	2.2	1.4	0.72	3.1	0.087	4.0	0.11
Error (-/+)	-92% / +170%	-96% / +240%	-94% / +190%	-93% / +150%	-96% / +250%	-85% / +200%	-95% / +210%
Base Flow	0.28	--	0.15	0.15	--	0.63	--
Error (-/+)	-96% / +270%	--	-100% / +660%	-100% / +660%	--	-83% / +80%	--
Lead (kg/year)							
Storm Flow	1.8	1.2	0.37	2.4	0.069	3.2	0.16
Error (-/+)	-94% / +220%	-94% / +190%	-98% / +300%	-94% / +180%	-95% / +220%	-92% / +250%	-94% / +200%
Base Flow	0.07	--	1.3	1.3	--	2.6	--
Error (-/+)	-93% / +170%	--	-100% / +660%	-100% / +660%	--	-110% / +180%	--

Table 5
Predicted Annual Mass Loading Based on Filtered Suspended Solids Samples
September 2009 through August 2010

	North MH108	North Central MH226	South Central MH369	South MH356	3-380 CB423	Total LS431	Parking Lot MH434
Zinc (kg/year)							
Storm Flow	8.0	7.9	4.4	18	0.75	22	0.89
Error (-/+)	-92% / +180%	-96% / +230%	-94% / +180%	-93% / +150%	-94% / +180%	-82% / +170%	-94% / +190%
Base Flow	0.75	--	1.4	1.4	--	3.7	--
Error (-/+)	-92% / +140%	--	-100% / +660%	-100% / +660%	--	-72% / +35%	--
Dioxin/Furan TEQ (kg/year)							
Storm Flow	8.0E-07	2.1E-07	9.0E-08	7.5E-08	2.2E-08	1.0E-06	5.5E-08
Error	-98% / +320%	-100% / +380%	-100% / +380%	-100% / +380%	-100% / +380%	-100% / +320%	-100% / +380%
Base Flow	4.2E-08	--	6.9E-11	6.9E-11	--	3.5E-08	--
Error	-98% / +310%	--	-100% / +660%	-100% / +660%	--	-100% / +150%	--

Table 6
Predicted Annual Mass Loading Based on Whole Water Samples
September 2009 through August 2010

	North MH108	North Central MH226	South Central MH369	South MH356	3-380 CB423	Total LS431	Parking Lot MH434
TSS (kg/year)							
Storm Flow	6,570	4,660	5,200	11,500	475	28,400	844
Error (-/+)	-90% / +130%	-93% / +140%	-93% / +140%	-93% / +140%	-93% / +140%	-75% / +110%	-93% / +140%
Base Flow	2,380	--	6,670	6,670	--	15,700	--
Error (-/+)	-92% / +140%	--	-100% / +280%	-100% / +280%	--	-70% / +25%	--
Total PCBs (kg/year)							
Storm Flow	0.0071	--	--	--	--	0.033	--
Error (-/+)	-140% / +210%	--	--	--	--	-93% / +140%	--
Base Flow	0.027	--	--	--	--	0.0082	--
Error (-/+)	-36% / +43%	--	--	--	--	-73% / +37%	--
Total HPAH (kg/year)							
Storm Flow	0.70	--	--	--	--	2.7	--
Error (-/+)	-120% / +190%	--	--	--	--	-91% / +140%	--
Base Flow	0.0065	--	--	--	--	0.10	--
Error (-/+)	-120% / +190%	--	--	--	--	-92% / +120%	--
Cadmium (kg/year)							
Storm Flow (Total)	0.18	--	--	--	--	0.58	--
Error (-/+)	-470% / +760%	--	--	--	--	-200% / +310%	--
Base Flow (Total)	0.80	--	--	--	--	6.3	--
Error (-/+)	-130% / +200%	--	--	--	--	-100% / +150%	--
Copper (kg/year)							
Storm Flow (Total)	4.1	--	--	--	--	10.7	--
Error (-/+)	-64% / +90%	--	--	--	--	-60% / +83%	--
Storm Flow (Dissolved)	1.4	--	--	--	--	2.4	--
Error (-/+)	-57% / +78%	--	--	--	--	-97% / +150%	--
Base Flow (Total)	0.36	--	--	--	--	0.73	--
Error (-/+)	-47% / +61%	--	--	--	--	-92% / +120%	--
Base Flow (Dissolved)	0.55	--	--	--	--	4.5	--
Error (-/+)	-110% / +160%	--	--	--	--	-97% / +140%	--
Lead (kg/year)							
Storm Flow (Total)	1.7	--	--	--	--	6.1	--

Table 6
Predicted Annual Mass Loading Based on Whole Water Samples
September 2009 through August 2010

	North MH108	North Central MH226	South Central MH369	South MH356	3-380 CB423	Total LS431	Parking Lot MH434
Error (-/+)	-88% / +130%	--	--	--	--	-76% / +110%	--
Base Flow (Total)	0.16	--	--	--	--	1.3	--
Error (-/+)	-57% / +79%	--	--	--	--	-94% / +130%	--
Zinc (kg/year)							
Storm Flow (Total)	20.9	--	--	--	--	68.0	--
Error (-/+)	-45% / +58%	--	--	--	--	-51% / +69%	--
Storm Flow (Dissolved)	13.0	--	--	--	--	28.7	--
Error (-/+)	-39% / +49%	--	--	--	--	-47% / +61%	--
Base Flow (Total)	1.6	--	--	--	--	8.7	--
Error (-/+)	-36% / +43%	--	--	--	--	-75% / +45%	--
Base Flow (Dissolved)	1.1	--	--	--	--	9.7	--
Error (-/+)	-120% / +180%	--	--	--	--	-98% / +140%	--

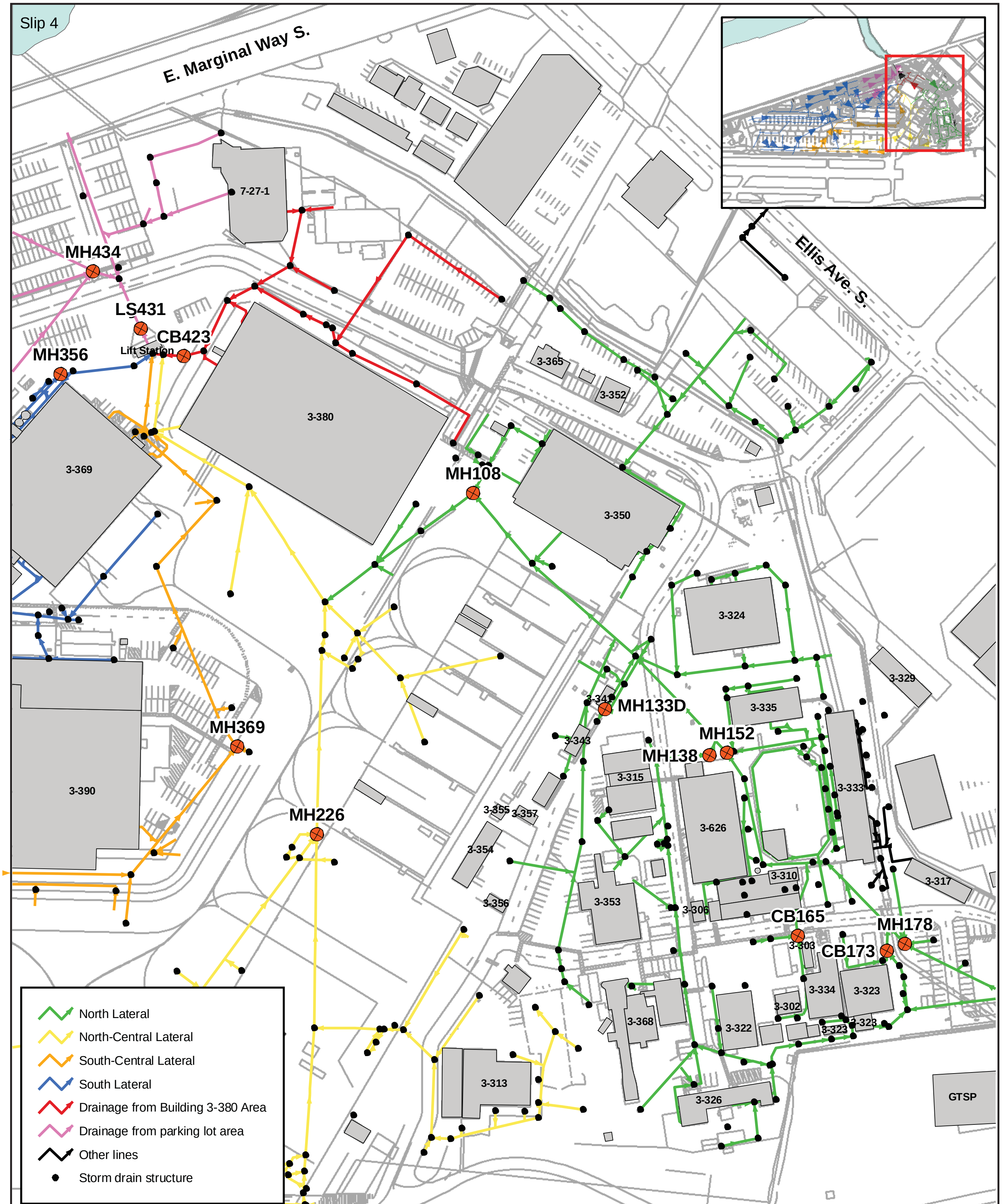

Figure 1. Expanded Stormwater Sampling Locations

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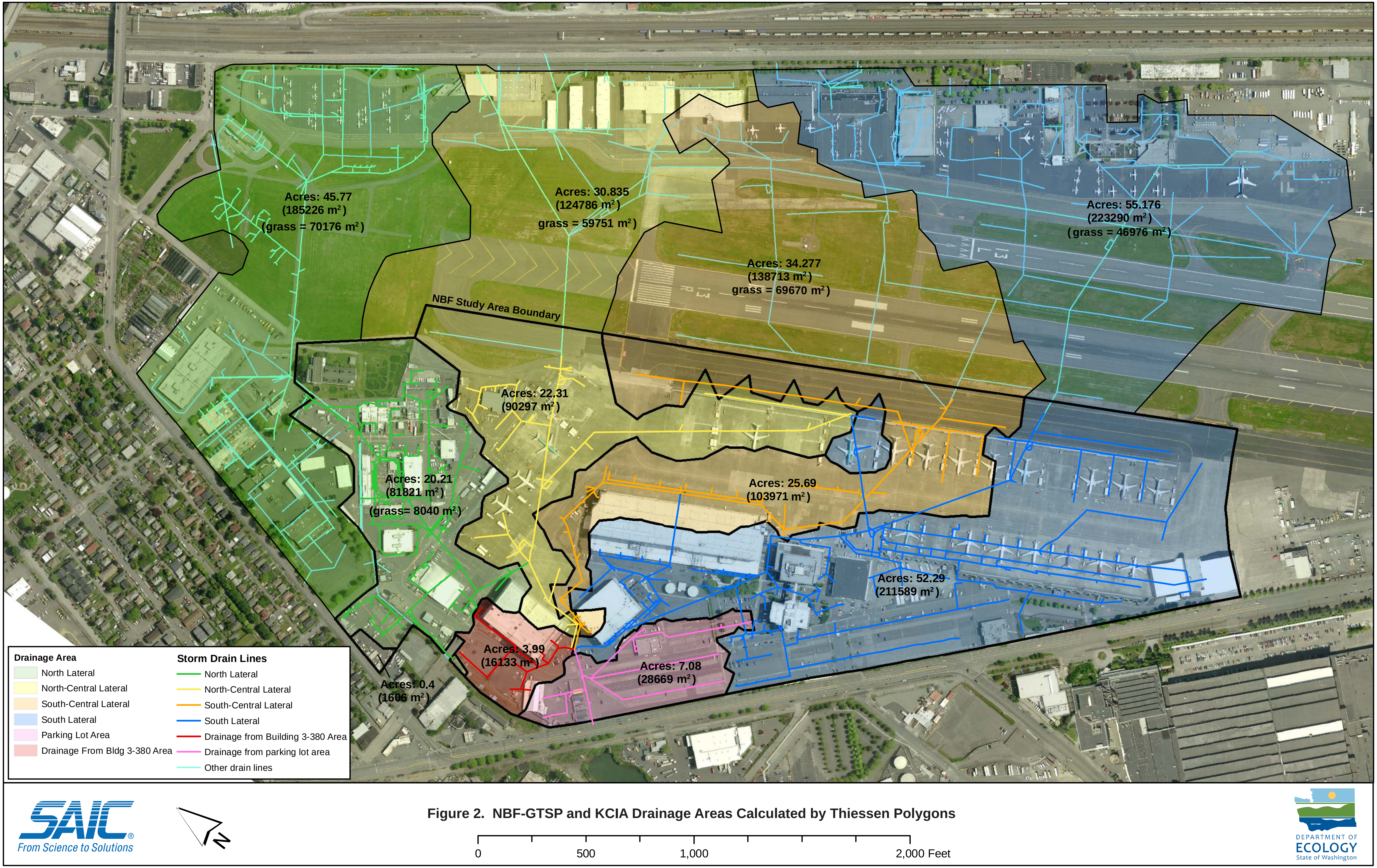

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Figure 2. NBF-GTSP and KCIA Drainage Areas Calculated by Thiessen Polygons

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Figure 3
Total PCB Loadings Relative to Lift Station (LS431)

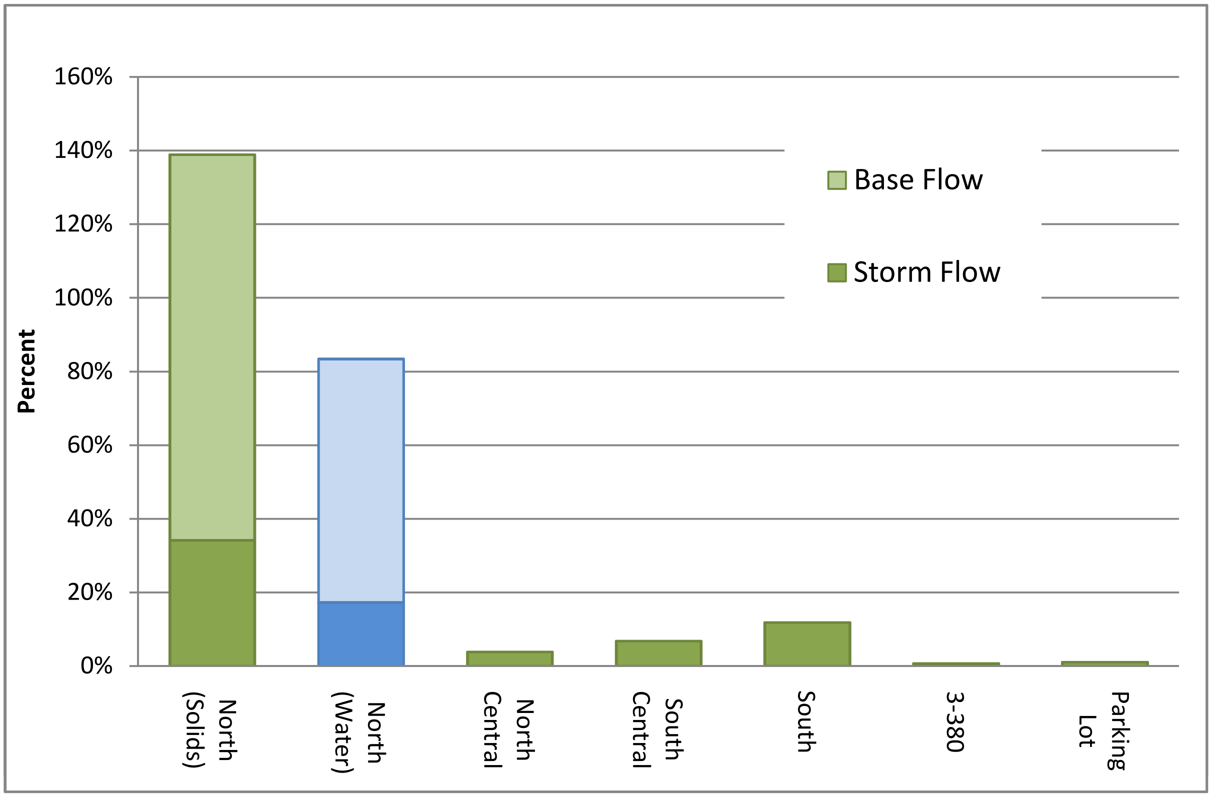

Figure 4
Total HPAH Loadings Relative to Lift Station (LS431)

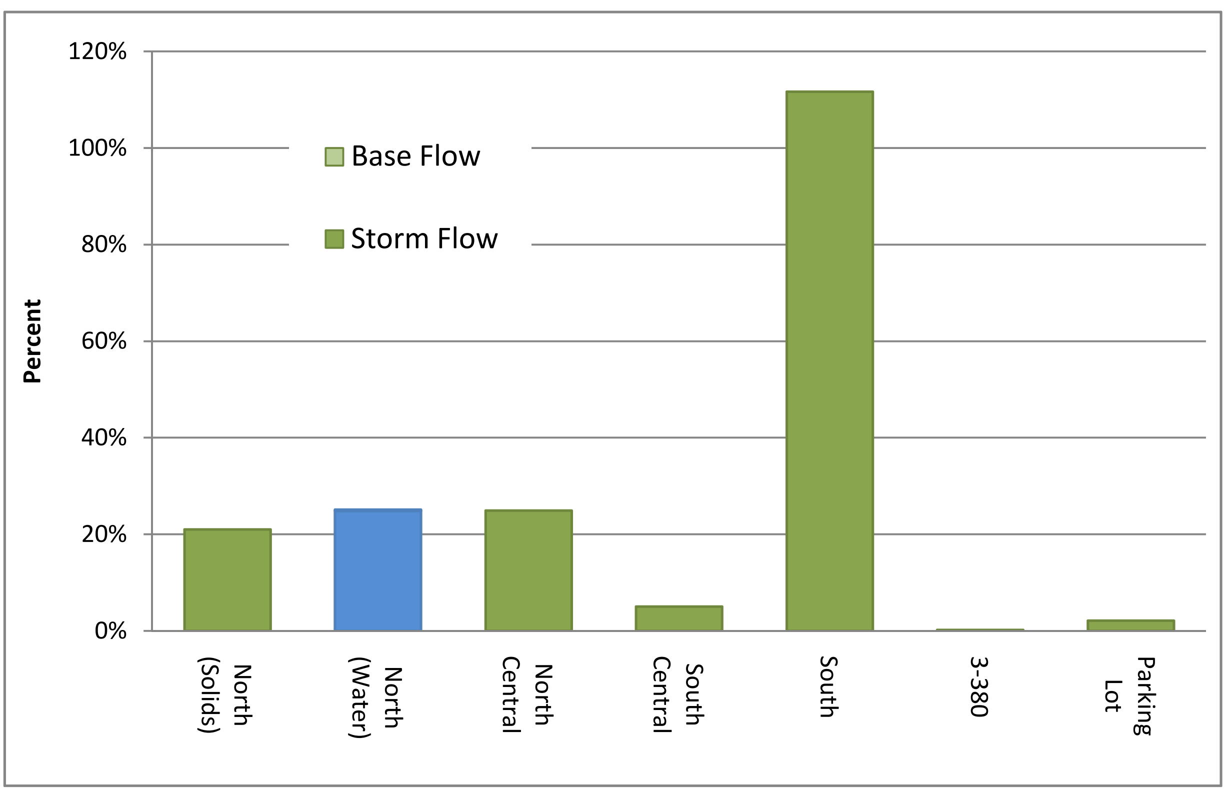

Figure 5
Mercury Loadings Relative to Lift Station (LS431)

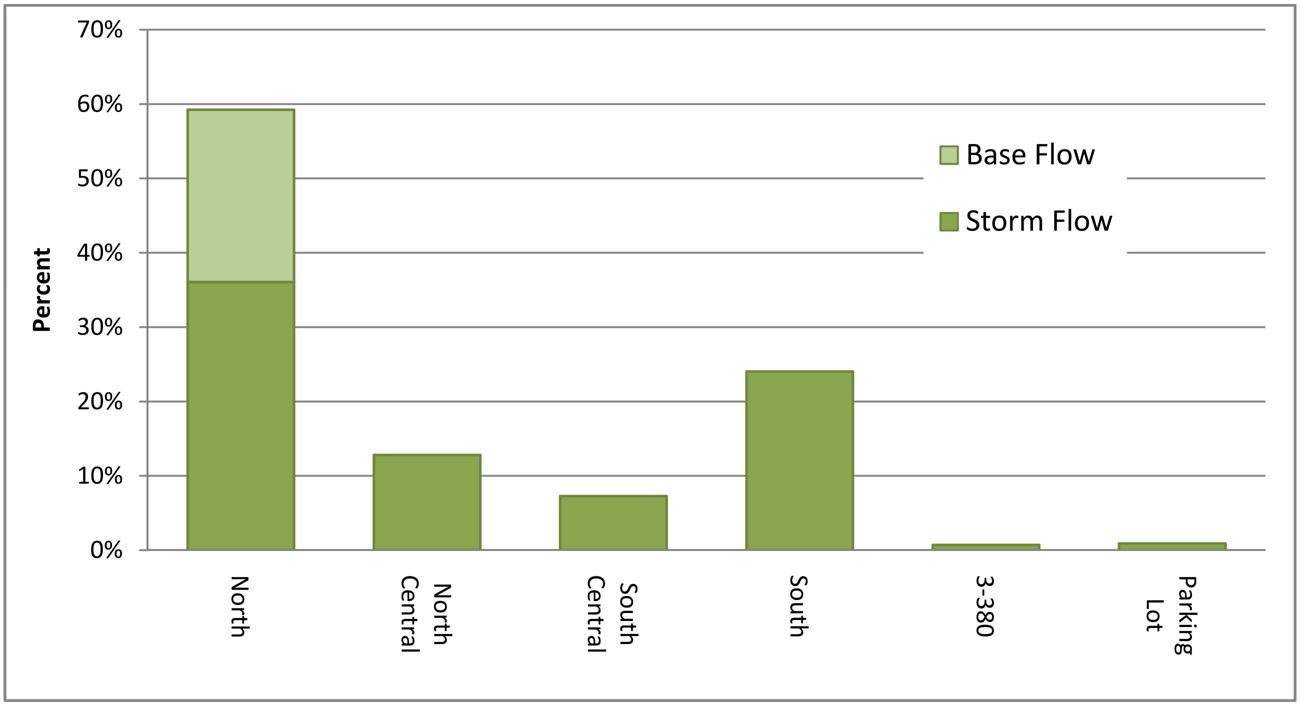

Figure 6
Cadmium Loadings Relative to Lift Station (LS431)

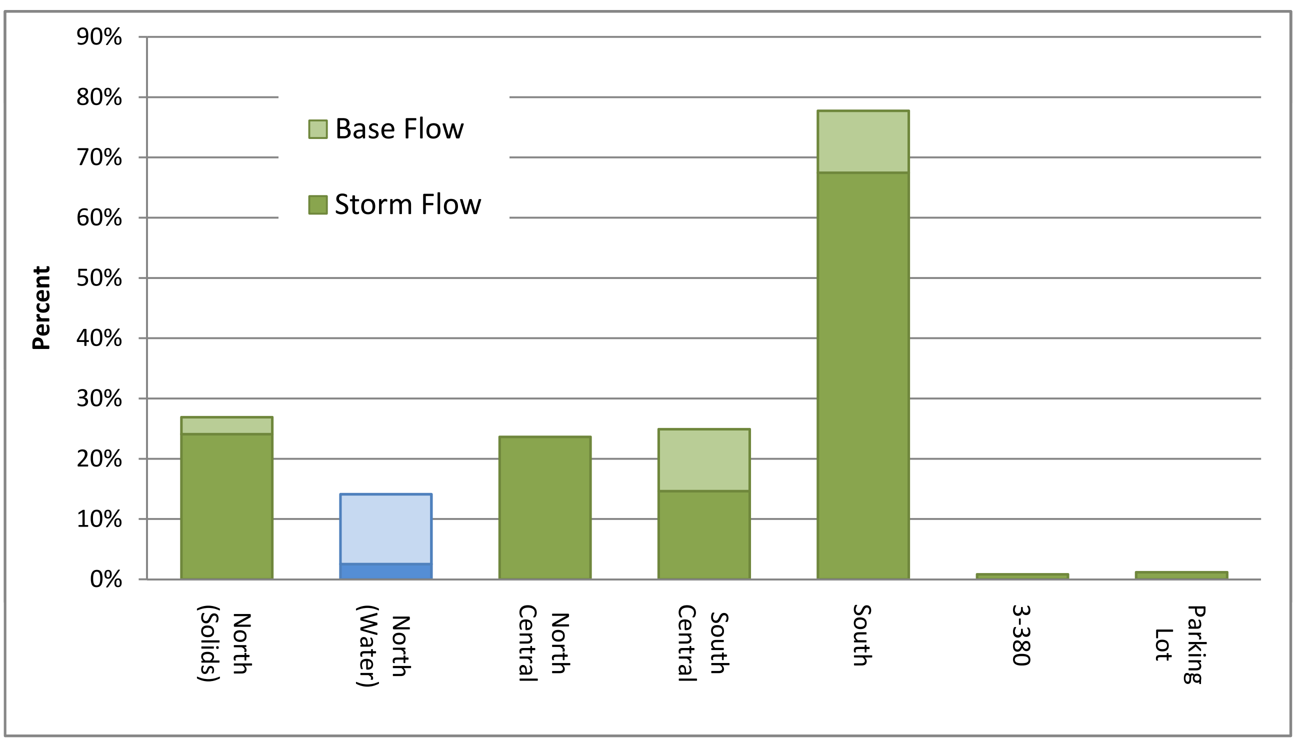

Figure 7
Copper Loadings Relative to Lift Station (LS431)

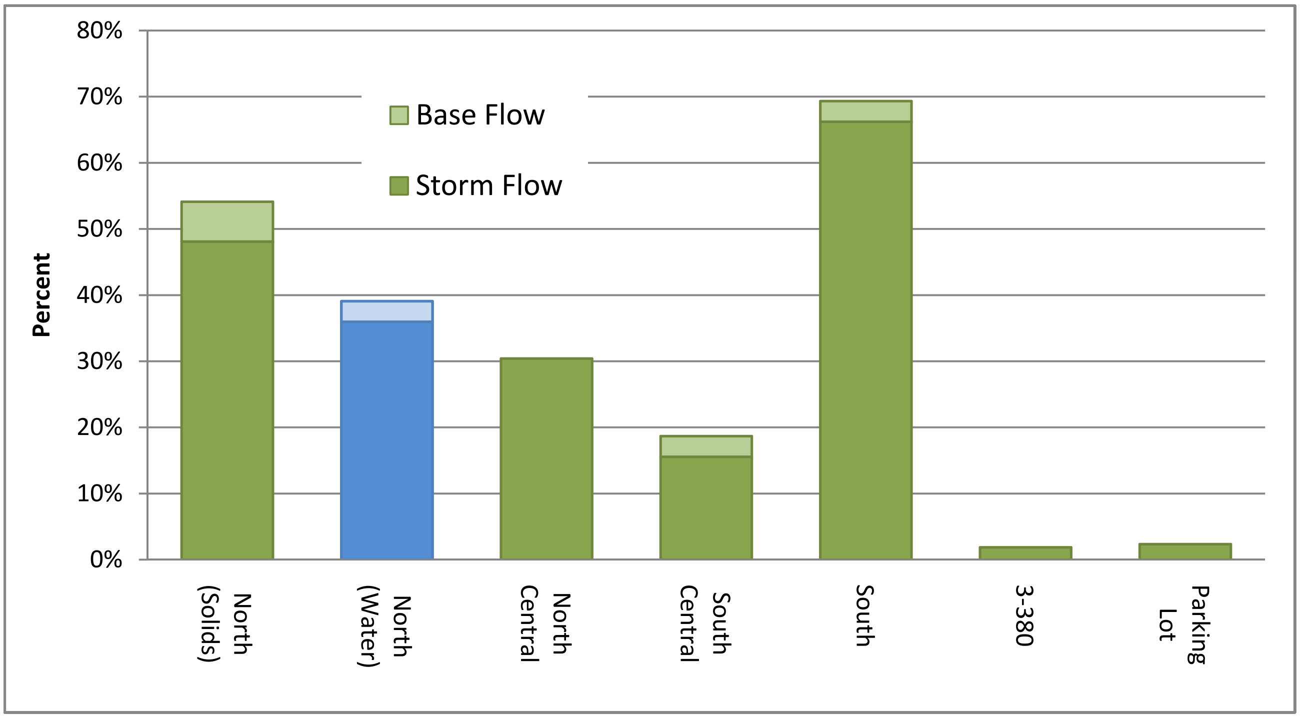

Figure 8
Lead Loadings Relative to Lift Station (LS431)

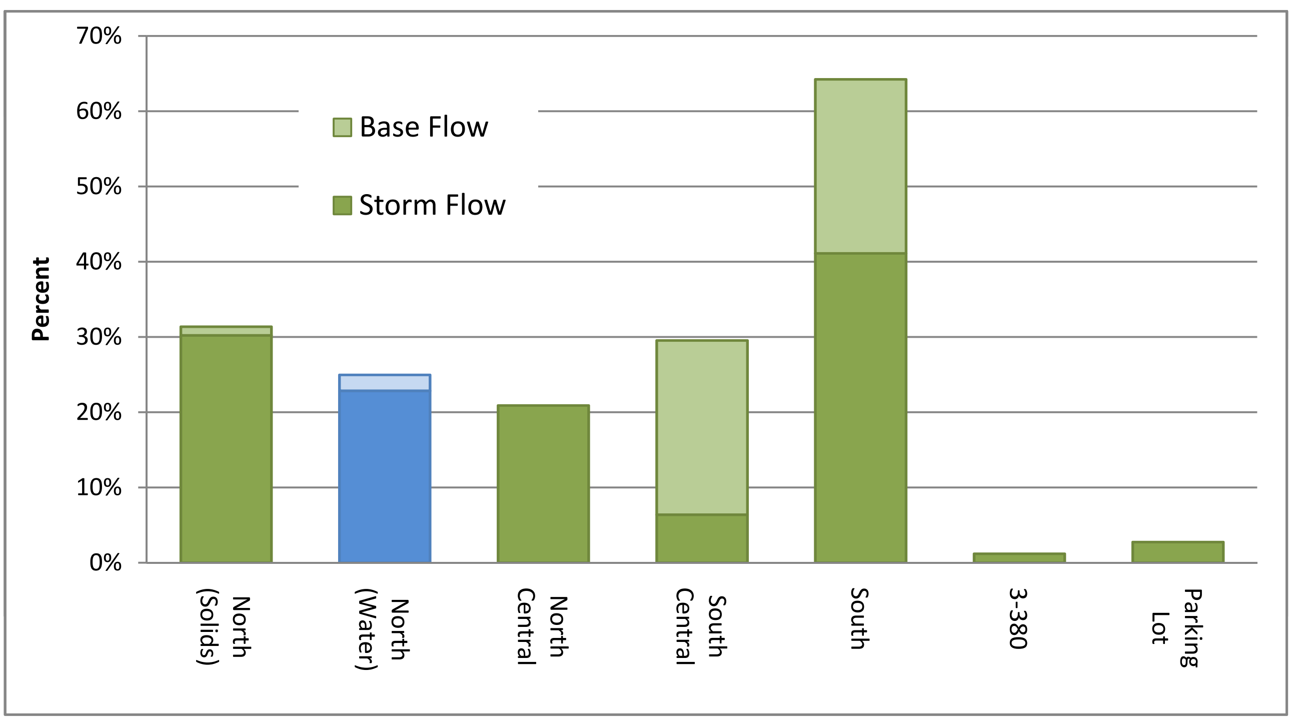

Figure 9
Zinc Loadings Relative to Lift Station (LS431)

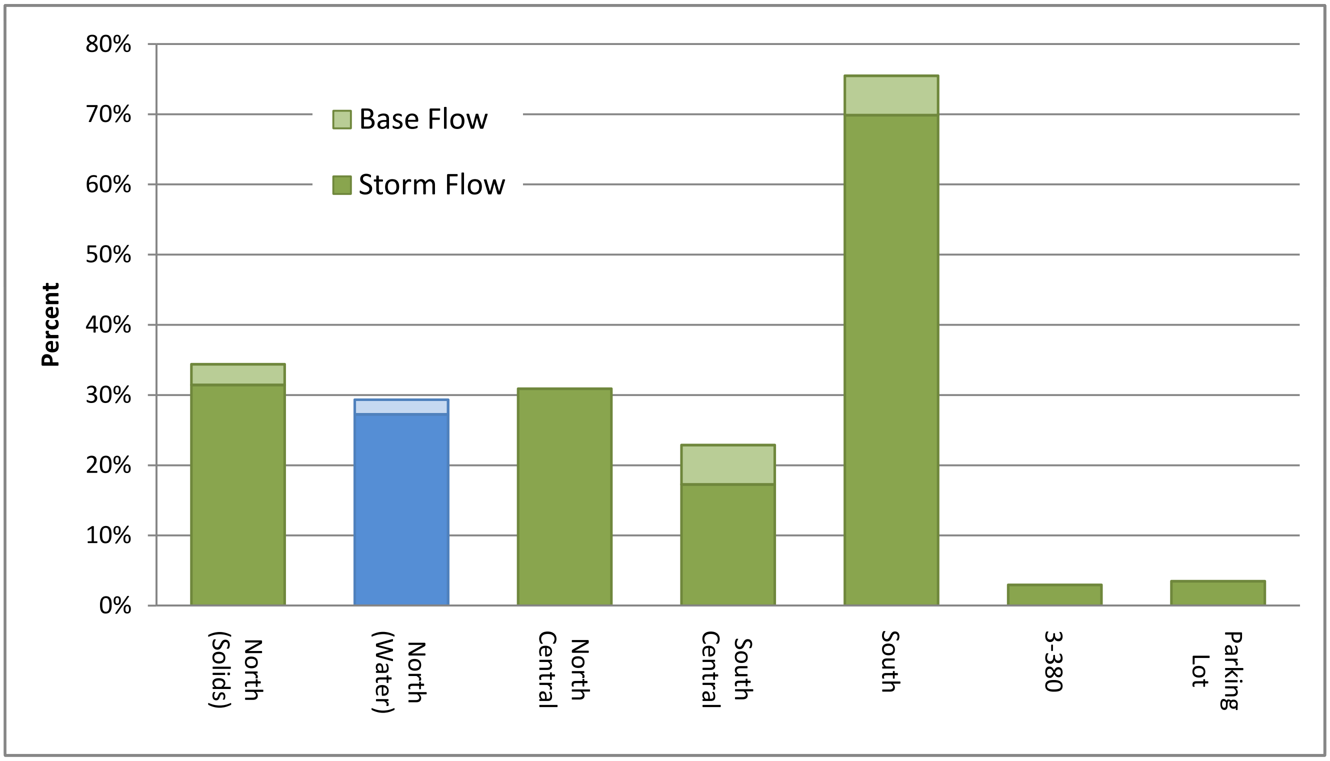

Figure 10
Dioxin/Furan TEQ Loadings Relative to Lift Station (LS431)